Fisheries and Oceans Canada | Pêches et Océans Canada
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Canadian Science Advisory Secretariat
Quebec Region | Science Response 2024/002

# UPDATE OF THE STOCK STATUS INDICATOR FOR GREENLAND HALIBUT IN THE GULF OF ST. LAWRENCE (4RST) IN 2023

## Context

The Gulf of St. Lawrence (NAFO Divisions 4RST) Greenland halibut (*Reinhardtius hippoglossoides*) stock is assessed and managed on a two-year cycle. In the intervening year, an update of the main indicator of the status of the resource is presented to determine if there has been a significant change in the status of the stock that may warrant adjustment of the Total Allowable Catch (TAC), initially determined for a period of two fishing seasons. At the last stock assessment (DFO 2023), it was agreed that in case of exceptional circumstances in an intervening year, for example a variation of more than 30% of the biomass indicator, the projected removals will be recalculated using the Precautionary Approach (PA) harvest control rule. The next full assessment of this stock is planned for winter 2025.

This Science Response Report results from the Regional Peer Review of November 27, 2023 on the Update of Stock Status Indicator for Greenland halibut in the Gulf of St. Lawrence (4RST) in 2023.

## Background

The indicator used to monitor stock status in intervening years is the biomass of individuals over 40 cm in the bottom trawl survey conducted by Fisheries and Oceans Canada (DFO) in the northern Gulf of St. Lawrence (nGSL). The time at sea to cover the study area of the nGSL survey was reduced by more than one-third in 2023 due to operational issues with the CCGS *John Cabot*, resulting in some areas that could not be sampled including the estuary. Two sets of analyses presented in Annex 1 suggest that confidence in the value of the indicator in 2023 is high. Additional information is also provided related to the landings and condition of Greenland halibut.

## Analysis and Response

### Environmental and ecological context

The Gulf of St. Lawrence (GSL) ecosystem has undergone significant changes in recent decades. Deep water warms and depletes oxygen (Galbraith et al. 2023). These changes appear to disadvantage cold-water species such as northern shrimp (*Pandalus borealis*) and Greenland halibut. The 2022 data show deep water warming and dissolved oxygen saturation levels reaching the lowest levels observed in Greenland halibut habitat. The massive arrival of redfish in the nGSL ecosystem results in and/or contributes to the intensification of direct (for food resources) or indirect (for habitat) interspecific competition interactions with Greenland halibut. Because they are long-lived species, they will share the ecosystem with Greenland halibut for many years to come.

## The fishery

The TAC for the 2023-2024 fishing season was 2,400 t and the fishing allocation available to the fixed gear fleets (F-ALL) was 1,960 t. The fishery was closed in NAFO subunits 4Tp (all season) and 4Tq (as of June 20, 2023) because of the high proportion of Greenland halibut under the legal size. As of November 10, 2023, landings totalled 156 t, including 154.8 t by fixed gear fleets, which is 7.9% of the F-ALL according to the Canadian Atlantic Quota Report (Figure 1). The 2023 landings are preliminary but are not expected to increase significantly as the fishing season continues until May 14, 2024. These are the lowest landings since 1970.

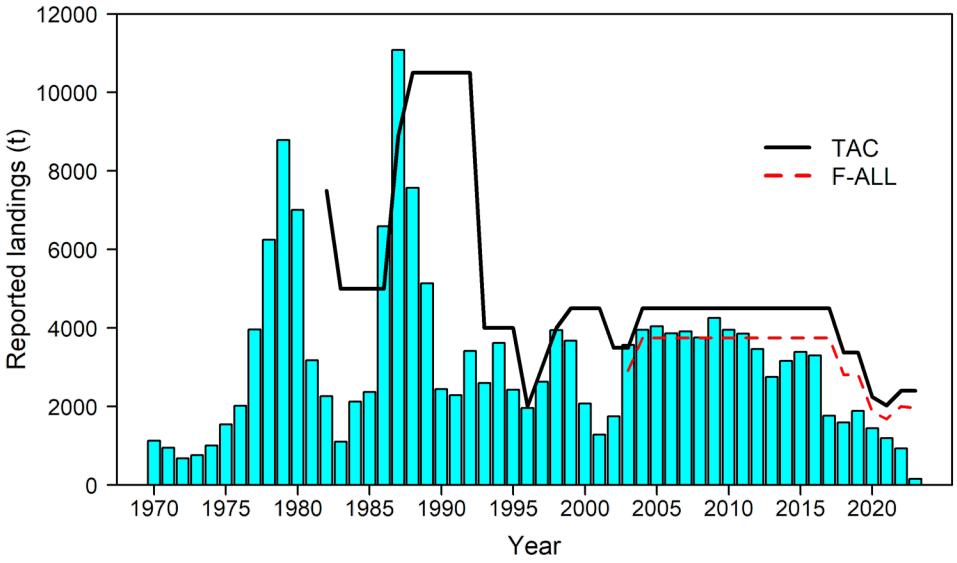


*Figure 1: Reported landings of Gulf of St. Lawrence Greenland halibut, total allowable catch (TAC) and fishing allocation (F-ALL) available to fixed gear fleets. Data for 2022 and 2023 are preliminary.*

## Condition index

In the last science advisory report on the status of the Greenland halibut stock, the low condition of individuals of all sizes in 2022 was identified as a concern due to its relationship with growth and survival (DFO 2023). The condition index was recalculated for the entire series excluding the strata not sampled in 2023 so that the 2023 value is comparable to the rest of the time series.

The estimated condition index for each Greenland halibut size had declined significantly and was well below average in 2022. In 2023, the condition indices for 35 and 45 cm individuals reached the lowest values in their respective series, while the condition of 15 and 25 cm individuals increased compared to 2022 and was at the average level (Figure 2). The mechanism that generated this decrease is unknown and several factors could explain it. However, the low conditions indices observed in 2022 were consistent with historically low levels of the two main prey species of Greenland halibut, capelin (*Mallotus villosus*) and northern shrimp (*Pandalus borealis*, Ouellette-Plante et al. 2020). Moreover, the low stomach fulness indices observed in 2022 supported this hypothesis (Chamberland and Benoît in press).

Low condition indices have been associated with decreased growth and increased natural mortality in Greenland halibut (Ghinter et al. 2021).

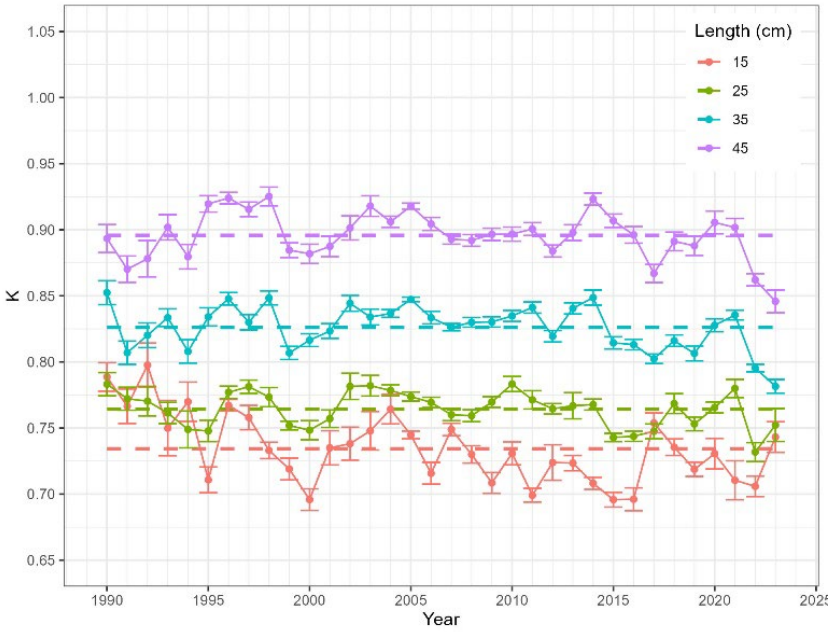


*Figure 2: Fulton condition indices (K) estimated for 15, 25, 35 and 45 cm Greenland halibut captured during the nGSL survey, excluding fish from strata not sampled in 2023. Error bars indicate the 95% confidence interval. The horizontal lines represent the average of each series*

## Precautionary Approach

A first precautionary approach was completed for the GSL Greenland halibut stock in 2022 (DFO 2022). It is based on empirical reference points and a harvest control rule. The indicator selected to monitor the status of the stock is the biomass of fish greater than 40 cm estimated from the nGSL survey.

The stock status indicator decreased by more than 60% between 2008 and 2017, moving from the healthy to the cautious zone. The indicator was stable in the middle of the cautious zone from 2017 to 2020. It increased to 35,859 t in 2021, remained at a similar level in 2022 (33,363 t) and decreased by 46% in 2023 compared to 2022 to reach 18,131 t (Figure 3A). Under the harvest control rule, removals should be a maximum of 823 t for the 2023-2024 management year (Figure 3B).

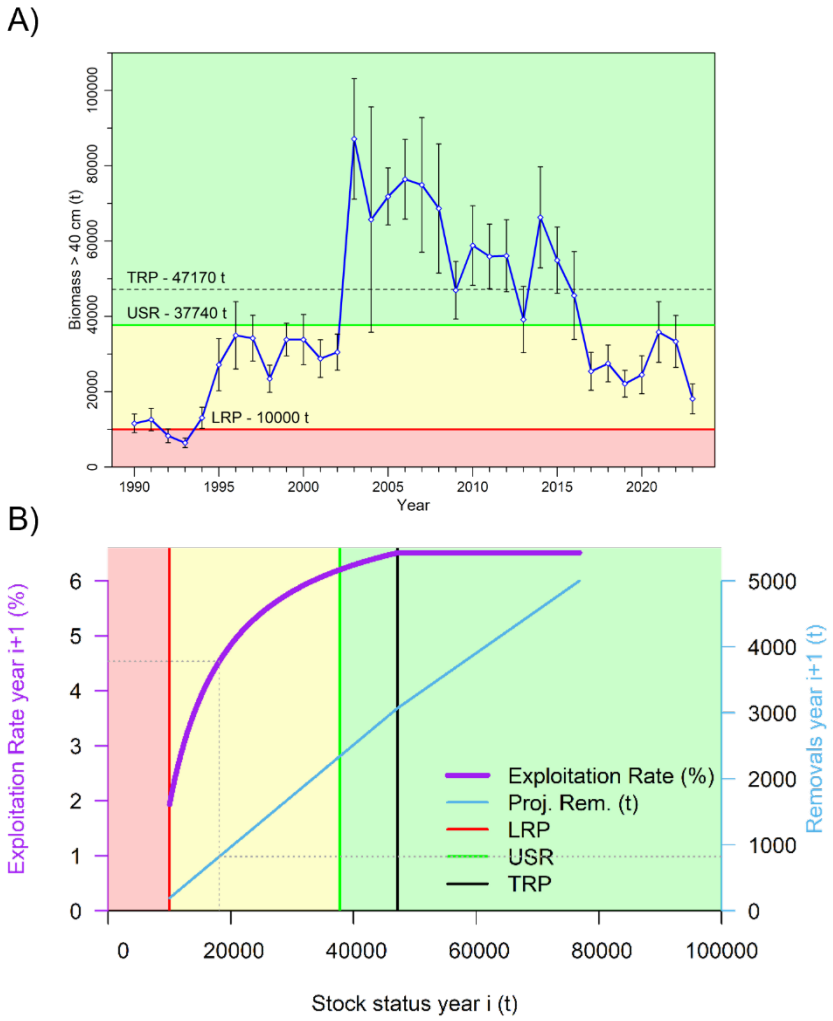


*Figure 3: (A) Biomass index of Greenland halibut greater than 40 cm estimated from the nGSL survey, with 95% confidence interval. The horizontal red line marks the Limit Reference Point (LRP) that delimits the critical (red) and cautious (yellow) zones. The horizontal green line marks the Upper Stock Reference point (USR) that delimits the cautious and healthy (green) zones. The dashed black line indicates the Target Reference Point (TRP). (B) Harvest control rule in terms of projected exploitation rate (purple) and removals (blue). The gray dashed lines indicate the projected exploitation rate and removals for the 2024-2025 fishing season.*

## Conclusions

The latest scientific advice on the stock status indicated that the long-term outlook for the Greenland halibut stock in the GSL is uncertain given ecosystem changes such as deep water warming, decreased dissolved oxygen and decreased prey abundance (DFO 2023). Low condition indices observed for larger fish in 2023, which may reflect a response to these changes, may be associated with slower growth and higher natural mortality.

In 2023, the stock status index decreased 46% from 2022 and was estimated at 18,131 t. Despite the poor spatial coverage of the nGSL survey in 2023, the primary indicator of stock status is reliable according to a sensitivity analysis and independent predictions using two other

scientific surveys. The stock is therefore at the lower part of the cautious zone. Under the PA's harvest control rule, removals from all sources should not exceed 823 t in 2024-2025.

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# Appendix 1

## Assessment of the impact of the low spatial coverage of the nGSL survey in 2023

Due to operational issues with the research vessel CCGS John Cabot in August 2023, sea time for the nGSL survey was reduced by one-third and the study area could not be fully covered. As a result, two areas were not sampled in 2023: the Strait of Belle Isle and the St. Lawrence Estuary west of Pointe-des-Monts (Figure A1). High densities of Greenland halibut are observed each year in the latter sector. In addition, sampling effort has been reduced in coastal areas, but these are typically characterized by low densities, or even the absence of Greenland halibut.

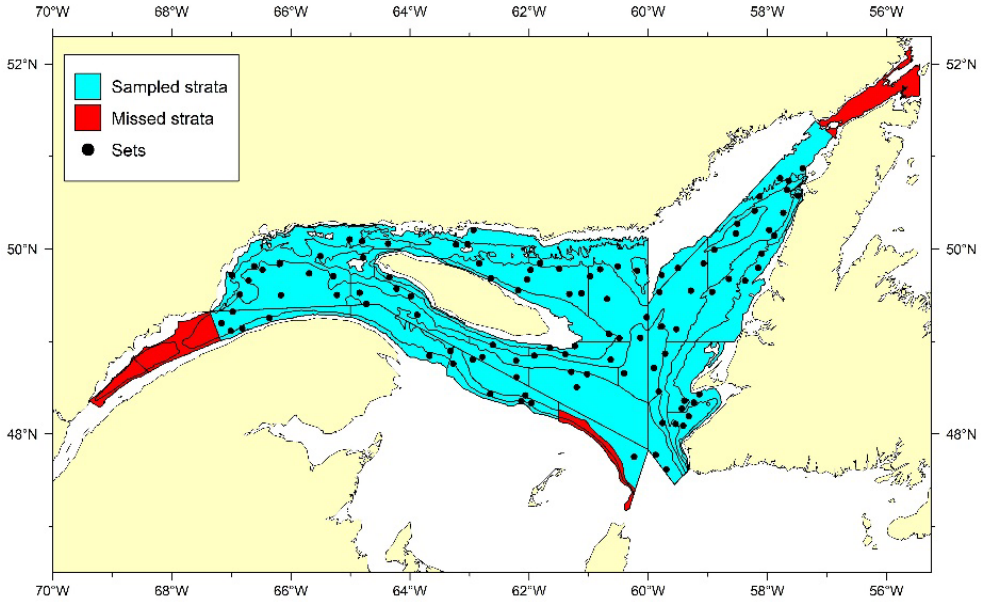


*Figure A1: Map of the 2023 nGSL survey showing, among the strata used to calculate the Greenland halibut stock status indicator, the strata sampled with at least one station, those not sampled, as well as successful fishing stations.*

Estimating a reliable annual indicator requires that it be calculated over a constant area for the entire time series. It is not uncommon for strata to be omitted during the annual nGSL survey. Catch rates for these strata are imputed using the following model model applied to blocks of years (Bourdages et al. 2023): log(catch + 0.01) ~ stratum + year. The reliability of this method for imputing values to large non-sampled areas, including areas of traditionally high abundance, is unknown.

Two sets of analyses were performed to establish confidence in the value of the indicator in 2023: a sensitivity analysis to the strata not sampled in 2023 and a comparison of the indicator estimated in the nGSL survey in 2023 with that predicted by the indices of the southern GSL (sGSL) and Mobile Sentinel Fisheries (MSF) surveys, which provide an abundance indicator consistent with the nGSL survey (Chamberland and Benoît in press).

### Sensitivity analysis on strata not sampled in 2023

A form of cross-validation was used to assess the reliability of the regression imputation method. In turn for each survey year (1990 to 2022), an absence of data and imputation were simulated for the strata that constitute the non-sampled zone in 2023. The traditional annual abundance index was subsequently compared to that derived from the simulation. The

correspondence between these two values demonstrates the reliability of the imputation method.

For the biomass indicator of individuals greater than 40 cm, the relationship between the traditional indicator and that with simulated imputation corresponded to a 1:1 relationship (Figure A2). This correspondence indicates that the reliability of imputation for a data year is high and does not lead to bias in the estimation of this indicator. In return, imputation of biomass in non-sampled strata in 2023 is associated with a bias in the estimation of the juvenile biomass index. For years of high recruitment, imputation tended to underestimate the annual biomass index by an average of 10%, while the bias seemed negligible for years of lower recruitment (Figure A2). This is related to the fact that juvenile Greenland halibut are mainly found in the estuary and that annual variations in recruitment are not constant in space (between strata).

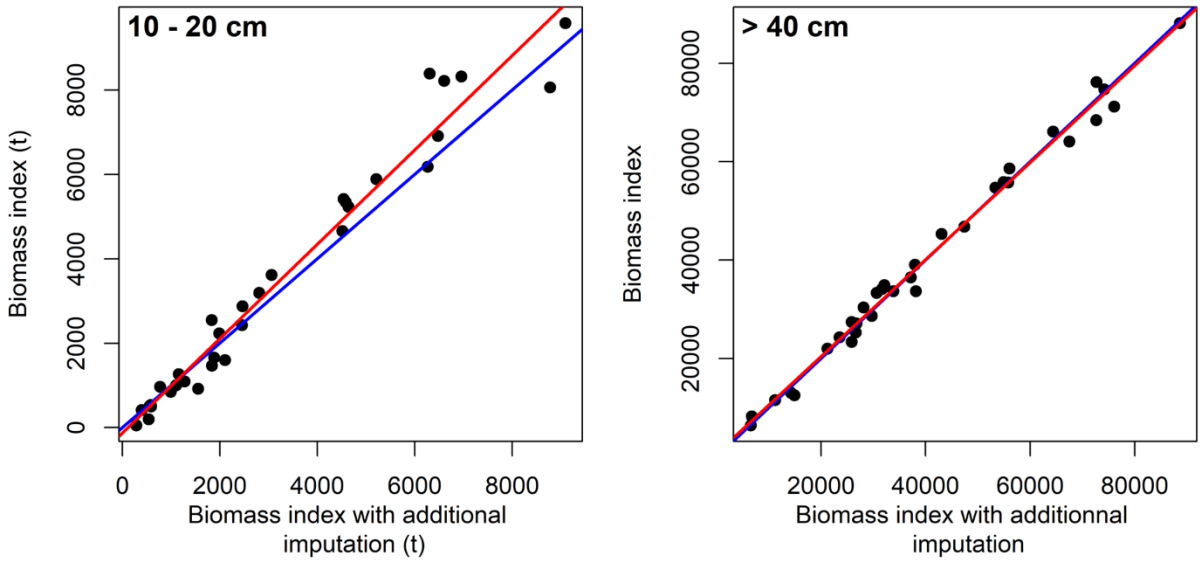


*Figure A2: Comparison of the Greenland halibut biomass index in the nGSL survey estimated with all available stations (traditional indicator) with that where an absence of data was simulated and filled by imputation, for individuals 10-20 cm and greater than 40 cm. The blue line represents line 1:1 and the red line represents the ordinary least squares regression.*

### Stock Status Indicator Prediction based on sGSL and PSM Survey Indicators

There is great consistency in the size structure and biomasses indices of the nGSL, sGSL and MSF scientific surveys (Chamberland and Benoît in press). The study areas of the sGSL and PSM surveys were fully covered in 2023. Analyses were therefore conducted to assess the ability to predict the main indicator of stock status based on indicators from these other two surveys.

A multiple linear regression was performed between the biomass of individuals greater than 40 cm in the nGSL survey, and those estimated in the sGSL and PSM surveys (excluding 2023 estimates). The predictive capacity of the model was evaluated with a jackknife cross-validation: each observed value of the index of the nGSL survey was compared to that predicted by the linear regression model calibrated without it.

The linear regression model predicted the biomass indices well since the value of the cross-validation coefficient of determination was high ($R^2$ = 0.716) and the prediction intervals

included the observed values at the expected frequency of 19 times out of 20 (Figure A"). On the other hand, the range of the regression model prediction intervals were generally larger than the range of the cautious zone, meaning that the accuracy of the latter is still limited in a decision-making context. The 2023 predicted biomass index value was 20,413 t, which would place the stock at the bottom of the cautious zone based according to this analysis and represents a 27% decrease compared to 2022.

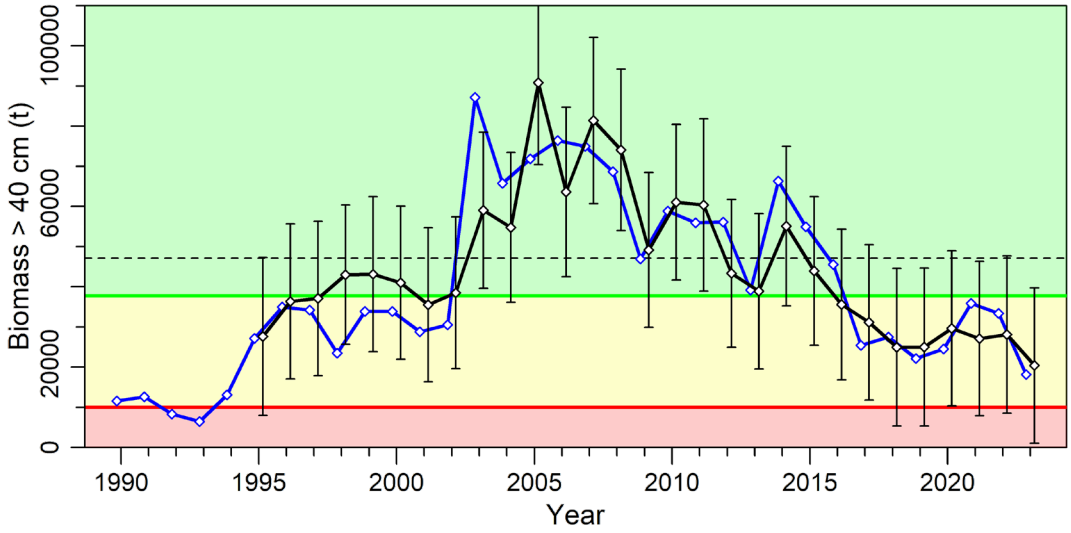


*Figure A3: Greater than 40 cm Greenland halibut biomass index in the nGSL survey and cross-validation predicted index using sGSL and MSP surveys. The error bars represent the 95% prediction intervals and the red, yellow and green zones the critical, cautious and healthy zones of the PA, respectively.*

The two series of analyses presented in this section therefore increase the confidence in the estimate of the stock status indicator in 2023. The estimate of the stock status indicator in 2023 seems reliable with the use of imputation despite the low spatial coverage of the nGSL survey. The independent prediction of the stock status indicator in 2023 from the sGSL and PSM surveys places the stock at the bottom of the cautious zone, as estimated with the nGSL survey in 2023. The impact of the low spatial coverage of the nGSL survey in 2023 on the reliability of two indicators for Greenland halibut therefore seems low. However, poor spatial coverage for more than one consecutive year may have a significant impact on these estimates.

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